METHODS AND SYSTEMS FOR TICKET VOUCHER FLOW CONTROL IN RESPONSE TO SIGNALING LINK FAILURE

AN APPLICATION FOR

UNITED STATES LETTERS PATENT

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"Express Mail" ma[illegible]mber: EK580751910US
Date of Deposit: A[illegible]8, 2000
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Description

METHODS AND SYSTEMS FOR TICKET VOUCHER FLOW CONTROL IN RESPONSE TO SIGNALING LINK FAILURE

Technical Field

The present invention relates to methods and systems for message flow control in response to signaling link failure. More particularly, the present invention relates to methods and systems for ticket voucher flow control in response to signaling link failure.

Background Art

In a common channel signaling network, such as an SS7 network, call signaling messages are used to set up and tear down calls between end users and to communicate with databases. These call signaling messages are sent over signaling links to a signaling node that routes the call signaling messages to the appropriate destination. The signaling links can be SS7 signaling links, IP signaling links, or other signaling links suitable for carrying call signaling messages. The node that conventionally handles such signaling links is referred to as a signal transfer point or a signaling gateway.

One problem with conventional signal transfer points or signaling gateways occurs when one of the signaling links fails. When a signaling link fails, messages directed to that link are buffered. The signal transfer point or

signaling gateway determines an alternate route to the destination and sends the buffered messages over an alternate outgoing signaling link (if available) that has not failed. Because SS7 signaling links are typically underutilized, i.e., only about 40% of total capacity is typically used, the message transfer rate of the outgoing signaling links can be increased relative to the message transfer rate of the incoming signaling links until all of the messages that were buffered for the failed signaling link have been transmitted. Once the signaling gateway transmits all of the buffered messages, the capacity of the outgoing signaling link can be decreased back to its normal level.

The process described above for responding to a signaling link failure works well only when the incoming and outgoing signaling links are low speed signaling links, i.e., capable of processing no more than about 300 messages per second. If the incoming signaling link is a high speed signaling link, i.e., capable of processing 2000 or more messages per second, the buffer used to store messages when the outgoing signaling link fails can quickly be overrun. In addition, even if the buffer is not overrun, it may take a long period of time for the outbound signaling link to deplete the messages stored in the buffer when another signaling link fails. Thus, there exists a need for novel methods and systems for performing flow control between incoming and outgoing signaling links in a signaling point when one or more of the signaling links fails.

Disclosure of the Invention

According to one aspect, the present invention includes methods and systems for flow control through a signaling node when a signaling link fails

using ticket voucher messages. As used herein, ticket voucher messages are messages transmitted between inbound and outbound communication modules to throttle the flow of call signaling messages when a signaling link fails. Ticket voucher messages have conventionally been used between link interface modules and signaling connection control part (SCCP) cards to indicate whether the SCCP cards have the capacity to perform operations, such as global title translation, on incoming messages. The present invention includes novel methods and systems for using ticket voucher messages to throttle traffic between communication modules in a signaling node when one or more signaling links fail.

The present invention will be explained below in terms of modules or processes for performing ticket voucher flow control. It is understood that these modules or processes may be implemented in hardware, software, or a combination of hardware and software. Accordingly, some embodiments of the present invention may be implemented as computer program products comprising computer executable instructions embodied in a computer readable medium.

Accordingly, it is an object of the present invention to provide novel methods and systems for performing flow control between communication modules in a signaling node when one or more signaling links fail.

Some of the objects of the invention having been stated hereinabove, other objects will be evident as the description proceeds, when taken in connection with the accompanying drawings as best described hereinbelow.

Brief Description of the Drawings

A description of the present invention will now proceed with reference to the accompanying drawings of which:

Figure 1 is a block diagram of an exemplary operating environment for embodiments of the present invention;

Figure 2 is a block diagram of a conventional signaling gateway to which ticket voucher flow control methods of the present invention may be applied;

Figure 3 is a block diagram illustrating the internal architecture of a signaling gateway including one or more ticket voucher flow control processes according to an embodiment of the present invention;

Figure 4 is a block diagram of a link interface module including a ticket voucher flow control process according to an embodiment of the present invention;

Figure 5 is a flow chart illustrating exemplary steps that may be performed by an MTP routing process modified to operate with a ticket voucher flow control process according to an embodiment of the present invention;

Figure 6 is a flow chart illustrating exemplary steps that may be performed by a ticket voucher flow control process in issuing a ticket voucher request according to an embodiment of the present invention;

Figure 7 is a block diagram illustrating an exemplary packet structure for a ticket voucher flow control message according to an embodiment of the present invention; and

Figure 8 is a flow chart illustrating exemplary steps that may be performed by a ticket voucher flow control process in processing a ticket voucher request according to an embodiment of the present invention.

Detailed Description of the Invention

Figure 1 illustrates an exemplary operating environment for embodiments of the present invention. In Figure 1, a signaling gateway **100** includes ticket voucher flow control processes **102** associated with signaling links **104** to regulate the flow of messages when one of the signaling links **104** fails. Signaling links **104** can be any type of signaling link used to communicate call signaling messages. For example, the signaling links can be SS7 signaling links, TCP/IP signaling links, or any other type of signaling links used to communicate call signaling messages. Signaling gateway **100** is preferably capable of receiving call signaling messages and routing the call signaling messages to the appropriate destination. In the illustrated embodiment, signaling gateway **100** is configured to communicate with a service switching point **106**, a signal transfer point **108**, a service control point **110**, and a media gateway controller **112**. However, the present invention is not limited to communicating with only these signaling nodes. The signaling nodes illustrated in Figure 1 are shown for illustrative purposes only.

With the exception of ticket voucher flow control process **102**, the internal architecture of signaling gateway **100** may be similar to that of the EAGLE® signal transfer point or the IP^7 SECURE GATEWAY™ available from Tekelec, Inc., of Calabasas, California (hereinafter, "Tekelec"). A detailed description of the EAGLE® STP may be found in EAGLE® Feature Guide

PN/910-1225-01, revision B, January 1998, published by Tekelec, the disclosure of which is incorporated herein by reference in its entirety. Similarly, a detailed description of the IP7 SECURE GATEWAY™ may be found in Tekelec publication PN/909-0767-01, revision B, August 1991, entitled "Feature Notice: IP7 SECURE GATEWAY™ Release 1," the disclosure of which is incorporated herein by reference in its entirety. The specific functions of the IP7 SECURE GATEWAY™ for transmitting and receiving TCAP messages over an Internet protocol network are described in PCT Publication No. WO 00/35155, the disclosure of which is incorporated herein by reference in its entirety. Similarly, the functional components of the IP7 SECURE GATEWAY™ for transmitting ISUP messages over an Internet protocol network are described in PCT Publication No. WO 00/35156, the disclosure of which is incorporated herein by reference in its entirety.

Figure 2 illustrates the internal subsystems of an EAGLE® STP or an IP7 SECURE GATEWAY™ to which the methods for performing ticket voucher flow control according to the present invention may be applied. In the illustrated embodiment, STP or signaling gateway **200** includes the following subsystems: a maintenance and administration subsystem (MAS) **202**, a communication subsystem **204**, and an application subsystem **206**. The maintenance and administration subsystem **202** provides maintenance communications, initial program loading, peripheral services, provisioning capability, alarm processing, and system disks. Communication subsystem **204** includes an interprocessor message transport (IMT) bus that is the main communication bus among all of the subsystems in signaling gateway **200**. In

a preferred embodiment, the interprocessor message transport bus includes two 125 Mbps counter-rotating serial buses.

Application subsystem **206** includes cards that are capable of communicating with other cards through the IMT bus. Numerous types of application cards can be incorporated in signaling gateway **200**. Examples of such cards includes a link interface module (LIM) **208** that provides SS7 and X.25 links, a data communications module (DCM) **210** that provides SS7-to-TCP/IP and TCP/IP-to-SS7 translation, and an application service module (ASM) **212** that provides global title translation, gateway screening, and other services. A translation service module (TSM) **214** may also be provided to support local number portability service. While multiple application modules or cards may be simultaneously configured and operatively connected to the IMT bus, it will be appreciated that each card is assigned a unique IMT bus address so as to generally facilitate the internal communication of messages between provisioned cards that are attached to the IMT bus. Once again, a detailed description of the EAGLE® STP other than DCM **210** is provided in the above-cited EAGLE® Feature Guide and need not be described in detail herein. DCM **210** is described in detail in the above-referenced International Patent Publications.

With regard to communication type modules, DCM card **210** can be used to communicate IP-encapsulated SS7 messages over an IP network, as described in the above-referenced Feature Notice IP7 SECURE GATEWAY™ release 1.0 publication. With regard to the TSM module and triggered LNP services mentioned above, a detailed description of the triggered LNP functionality of an STP or a signaling gateway can be found in Feature Guide:

LNPLSMS PN/910-158-01, revision A, January 1998, published by Tekelec, the disclosure of which is incorporated herein by reference in its entirety. Furthermore, systems and methods for providing triggerless LNP functionality within a network routing node are described in commonly-assigned, copending U.S. Patent Application No. 09/503,541, filed February 14, 2000, the disclosure of which is incorporated herein by reference in its entirety.

Figure 3 is a block diagram of an exemplary internal structure of signaling gateway **100** according to an embodiment of the present invention. For convenience, only the interface modules that communicate with external call signaling links are illustrated. It is understood that signaling gateway **100** may include other modules, such as LIMs, DCMs, TSMs, ASMs, etc., as discussed above with respect to Figure 2. In the illustrated embodiment, signaling gateway **100** includes Internet protocol link interface modules (IP LIMs) **300, 302, 304,** and **306** for communicating with external nodes over signaling links **104**. Although the IP LIMs can be configured to communicate with any number of external signaling links, in Figure 3, each IP LIM manages two signaling links **104**.

Each of the Internet protocol link interface modules **300, 302, 304,** and **306** may be a separate card or printed circuit board with its own resident microprocessor and memory devices. Alternatively, IP LIMs **300, 302, 304,** and **306** may be separate processes executing on the same microprocessor using a time sharing algorithm. In the illustrated embodiment, IP LIMs **300, 302, 304,** and **306** are connected to each other by an interprocessor message transport bus **308**. IMT bus **308** may be a dual-ring, counter-rotating bus for providing additional reliability in the event that one of the Internet protocol link

interface modules fails. IMT bus **308** carries messages, such as call signaling messages, between Internet protocol link interface modules and any other modules included in signaling gateway **100**. In addition, according to the present invention, IMT bus **308** carries ticket voucher request and grant messages between Internet protocol link interface modules **300**, **302**, **304**, and **306**. The generation and transfer of the ticket voucher grant and request messages will be discussed in more detail below.

Figure 4 is a block diagram illustrating an Internet protocol link interface module according to an embodiment of the present invention in more detail. In Figure 4, Internet protocol link interface module **300** includes a plurality of processes for handling incoming and outgoing messages as well as processes for performing ticket voucher flow control according to embodiments of the present invention. For example, Internet protocol link interface module **300** includes an SS7/IP and IP/SS7 converter **400** for converting messages between SS7 and IP and vice versa. L2 to L3 queue **402** stores SS7 messages between SS7 layer 2 and layer 3 processes. Message handling and discrimination (HMDC) process **404** determines whether an inbound SS7 message is directed to this signaling gateway or to another signaling node. This determination may be based on the MTP routing label in the SS7 message. If HMDC process **404** determines that the message is directed to this signaling node, HMDC process **404** routes the message to message handling and distribution (HMDT) process **406** to be routed to an internal card for further processing. An example of such a message that requires further processing is a message that requires global title translation. Such processing is not of importance to the present invention.

Accordingly, in the remaining explanation, it is assumed an incoming message is routed to an external node.

Once HMDC process **404** determines that a message is to be routed to an external signaling node, HMDC process **404** forwards the message to MTP routing process **408**. MTP routing process **408** examines signaling information in the message and determines the internal IMT bus address of the communications module that manages the outbound signaling link to which the message is addressed. According to the present embodiment, MTP process **408** also communicates with ticket voucher flow control process **402** to regulate message flow in the event of a link failure.

Figure 5 illustrates exemplary steps that may be performed by MTP routing process in regulating message flow based on ticket voucher grants according to an embodiment of the present invention. Referring to Figure 5, in step **ST1**, MTP routing process **408** selects an outgoing signaling linkset and a link within the linkset based on the destination point code and signaling link selection code in a message. In SS7 communications, a link is a path to an adjacent node. Links are placed into groups, which are referred to as linksets. All links in a linkset are capable of accessing the same adjacent signaling node. In step **ST2**, MTP routing process **408** determines whether the outgoing signaling linkset is on hold. Determining whether a linkset is on hold can be accomplished by reading a flag in a routing table associated with the linkset. The flag may be set by SS7 traffic management processes when a link fails. The following is a sequence of events that may occur in a signaling gateway or a signal transfer point when a signaling link fails:

1. A link in a linkset becomes unavailable.
2. The communication module associated with the link notifies other modules that its link is unavailable.
3. The MTP routing functions associated with each communication module flag the linkset as on hold. MTP layer 3 functions associated with the communication module having the failed linkset send a changeover message to the adjacent node and start a sequence timer to prevent race conditions from occurring.
4. A message addressed to the on-hold linkset arrives at one of the communication modules and is enqueued because the linkset is on hold.
5. The linkset goes off-hold because a) the sequence timer expires, or b) a changeover acknowledgement message received from adjacent node.
6. Messages queued while linkset was on hold are now routed, using ticket voucher messages for pacing.

In step **ST3**, if MTP routing process determines that the linkset is not on hold, MTP routing process **408** simply routes the message to the outgoing link. However, in step **ST4**, if MTP routing process **408** determines that the linkset is on hold, MTP routing process **408** places the message in ticket voucher queue **410**. Ticket voucher queue **410** stores the message until a ticket voucher request is granted for the message or until the message is dequeued by a background process adapted to send MSUs at a low-speed rate, such as 600 MSUs/sec, or until it becomes necessary to discard the message. The operation of ticket voucher queue **410** and the granting and

requesting of ticket vouchers will be discussed in more detail below. Once MTP routing process places the message in the ticket voucher queue, control returns to step **ST1** where the MTP routing process **408** processes the next message.

Figure 6 illustrates exemplary steps that may be performed by ticket voucher request generator/grant processor **412** in formulating ticket voucher requests and processing ticket voucher grants according to an embodiment of the present invention. The steps illustrated in Figure 6 assume that the linkset to which MSUs in the ticket voucher queue are addressed has gone off-hold. In step **ST1**, ticket voucher request generator/grant processor **412** determines whether MSUs are present in ticket voucher queue **410**. In step **ST2**, if ticket voucher request generator/grant processor **412** determines that MSUs are not present, ticket voucher request generator/grant processor **412** continues checking. If ticket voucher request generator/grant processor **412** determines that MSUs are present in ticket voucher queue **410**, ticket voucher request generator/grant processor **412** issues a ticket voucher (TV) request and waits for a grant. In order to issue a TV request, ticket voucher request generator/grant processor formulates a TV message and sends the TV message over the IMT bus.

Figure 7 illustrates an exemplary packet structure for a TV message according to an embodiment of the present invention. In the illustrated embodiment, TV message **700** includes a destination address field that specifies the destination address for the TV message. According to the present embodiment, the destination address is an IMT bus hardware address within signaling gateway **100**. Because it is desirable to ensure that all of the

candidate communications modules on the IMT bus receive the message, the destination address **702** is preferably that of the message originator. For example, because the IMT bus is of the ring design, the ticket voucher request message will pass through each communications module connected to the IMT bus and eventually return to the originator.

Ticket voucher request message **700** includes a group/member number field **704** for storing a group number or a member number. The group number is specified in a TV request to identify the type of cards for receiving the request. For example, one group number may indicate that the request is directed to all LIM cards. The member number is used to distinguish between linksets when changeovers occur simultaneously on more than one linkset. For example, if two different linksets are on hold simultaneously, ticket voucher requests from different cards may be issued simultaneously. Cards associated with both linksets may each issue a single grant for the associated request. Since grants are routed to all cards until they are consumed, one card could receive two grants and send MSUs at twice the desired rate and another card would receive no grants. Thus, if there is no way for the requestor to distinguish between grants, some cards could be "starved" and other cards could receive more than their share of grants.

To alleviate these problems, the member number is used to distinguish among linksets. If the grant does not contain the expected member number, the grant is ignored. Request/grant indication field **706** stores a value that indicates whether the ticket voucher flow control message **700** is a request or a grant. Grantor present indication field **708** stores a value which is used to indicate whether a grantor is present for the message. Time-to-live field **710**

stores a time-to-live or hop count value that is decremented by each communications module that receives a request to prevent messages from looping endlessly within signaling gateway **100**. Checksum field **712** stores a value for indicating whether ticket voucher flow control message **700** has an error.

Returning to Figure 6, in step **ST4**, ticket voucher request generator/grant processor **412** determines whether a grant has been received. In step **ST5**, if a grant has been received, ticket voucher request generator/grant processor **412** determines whether the grant contains the expected member number. If the grant does not contain the expected member number, ticket voucher request generator/grant processor **412** ignores the grant and control returns to step **ST3** where a new request is issued. If ticket voucher request generator/grant processor **412** determines that the received grant is from the card in the expected linkset, in step **ST6**, ticket voucher request generator/grant processor sends the MSU at the head of the ticket voucher queue to an outbound communication module, as determined by the SLC and DPC in the MSU. It is not necessary that the outbound communication module be the grantor of the request.

Returning to step **ST4**, if a message other than a grant is received, control proceeds to step **ST7**. In step **ST7**, ticket voucher request generator/grant processor **412** determines whether grantor present field in a received message is set to "true" but no grants are available. If the received message indicates that a grantor is present but no grants are available, ticket voucher request generator/grant processor **412** preferably issues a new request, with the expectation that grants will later become available. In this

case, it may be desirable to wait for a predetermined time period before issuing a new request in order to allow sufficient time for grants to become available. In step **ST7**, if a ticket voucher message is received and indicates that no grantors are available, an error condition occurs and control may return to step **ST1**. As seen from Figure 6, ticket voucher requests can be used to perform flow control when a link in a linkset fails.

Figure 8 illustrates exemplary steps that may be performed by ticket voucher request processor/grant manager **414** illustrated in Figure 4 in processing a ticket voucher request and managing ticket voucher grants. Referring to Figure 8, in step **ST1**, ticket voucher request processor/grant manager **414** receives a ticket voucher request from the IMT bus. In step **ST2**, ticket voucher request processor/grant manager **414** determines whether the ticket voucher request is addressed to its group. This can be determined by examining the group number in field **704** of ticket voucher message **700**. In step **ST3**, ticket voucher request processor/grant manager **414** determines whether the request has been granted. This can be determined by examining request/grant indication field **706**. In step **ST4**, if the request has not been granted, ticket voucher request processor/grant manager **414** determines whether its communications module has any grants available. The determination as to whether any grants are available may be performed by monitoring the capacity of the outgoing signaling link associated with the interface module that received the grant.

In step **ST4**, if a grant is available, control proceeds to step **ST5** where ticket voucher request processor/grant manager **414** issues a grant to the requesting card according to a predetermined burst prevention function. For

example, the card issuing the grant may have an outbound signaling link capacity to send 1000 MSUs per second. If 1000 MSUs were enqueued in the TV queue, the associated card would issue 1000 back-to-back requests, and without any burst management function, the card with available outbound processing capacity would issue 1000 back-to-back grants. The 1000 grants would produce a burst of MSUs to be sent over the outbound signaling link in the first part of the available second and no MSUs during the remainder of the second. Bursty traffic is more susceptible to loss and hence is undesirable. Accordingly, the present invention applies a burst management algorithm when issuing ticket voucher grants.

According to the grant management algorithm, the available time slot for sending MSUs is divided into predetermined intervals. For example, if the time slot is 1 second, the predetermined intervals may be 5 milliseconds. Next, a predetermined number of grants are issued during each time interval. If the available bandwidth is 1000 MSUs/sec. and the intervals are 5 ms, then the number of grants issued during each time interval may be 5. Issuing 5 grants every 5 ms results in a total of 1000 MSUs/s, which is the available bandwidth in this example. Such spacing may be accomplished using a grant timer to control the issuance of grants. For example, the timer may be set to the interval (5 ms). When the timer expires, grants are issued, and the timer is reset. No grants are issued until the timer expires. Sending 5 MSUs every 5 milliseconds for one second uses the same average bandwidth over the one second interval as sending 1000 MSUs every 100 ms. However, the latter is more bursty. The present invention solves this problem by using a grant timer to smoothly space grant issuance over an available time slot.

In order to issue a grant, request processor/grant manager **414** changes request/grant indication field **706** to a value that indicates that the message is a grant and changes the group/member number field to the member number associated with the linkset of the card that issued the grant. Control then returns to step **ST1** to process the next request.

Returning to step **ST4**, if the card receiving the ticket voucher request determines that no grants are available, control proceeds to step **ST6** where the grantor present indication in the message is set to true. In step **ST7**, the time-to-live value in the message is checked. If the TTL value is greater than zero, the TTL value is decremented and the message is forwarded to the next card (step **ST8**). If the TTL value is not greater than zero, the message is discarded (step **ST9**).

Returning to step **ST2**, if the request is not addressed to the group of the receiving card, ticket voucher request processor/grant manager **414** determines whether the time-to-live value in the message is greater than zero (step **ST7**). If the time-to-live value is greater than zero, ticket voucher request processor/grant manager **414** decrements the TTL value in the message and forwards the message to the next card time-to-live (step **ST8**). If the time-to-live value is not greater than zero, in step **ST9**, ticket voucher request processor/grant manager **414** discards the message. This prevents excessive looping on the IMT bus. Once the message has been either forwarded or discarded, control returns to step **ST1** to process the next ticket voucher request. Accordingly, the steps in Figure 8 illustrate exemplary steps that may be performed in processing ticket voucher requests. Such steps

allow receiving cards to efficiently communicate their outgoing link processing capability to a requestor.

The ticket voucher flow control system according to embodiments of the present invention performs efficient flow control when a link in a linkset fails. By controlling the flow of MSUs based on ticket voucher request and grant messages, the present invention efficiently regulates the flow of enqueued MSUs to outbound signaling links. The present invention also includes mechanisms for distinguishing between ticket voucher grants when cards associated with two or more linksets simultaneously issue grant messages.

Although the embodiments illustrated in Figures 3 and 4 include ticket voucher flow control functionality located on link interface modules **300**, **302**, **304**, and **306**, the present invention is not limited to such an embodiment. For example, in an alternate embodiment of the invention, a centralized grantor module may monitor the capacity of all outbound signaling links and issue ticket voucher grants in response to the requests, as described above with regard to Figure 8.

It will be understood that various details of the invention may be changed without departing from the scope of the invention. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation—the invention being defined by the claims.